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Technical Report

PACKAGED AUTOMATIC FIRE PROTECTION SYSTEMS FOR REMOTE BUILDINGS

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PACKAGED AUTOMATIC FIRE PROTECTION SYSTEMS FOR REMOTE BUILDINGS

Technical Report R-520

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by

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ABSTRACT

The Naval Facilities Engineering Command has requirements for packaged automatic fire protection systems suitable for use in any climate, including polar. A research firm under contract to NCEL evaluated 31 fire-suppressant agents, and prepared conceptual designs of five protection systems, ranking the concepts on the basis of fire extinguishing characteristics, initial and maintenance costs, and reliability. The Halon 1301 Multicycle Total Flooding System was first choice and an automated water sprinkler system was second choice. Fire tests of these two systems by the contractor indicated that the Halon 1301 system is the more promising for an advanced base in a polar climate. However, because a fire protection system was required for immediate use in the Antarctic and the Halon 1301 system would require considerable development time, a water sprinkler system already proven in service was selected. This system designed by NCEL and discussed in this report is fully automated. It is a single-shot system, pressurized with nitrogen, and uses electric heaters to prevent the stored water from freezing.

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The Laboratory invites comment on this report, particularly on the results obtained by those who have applied the information

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INTRODUCTION

The Naval Facilities Engineering Command (NFEC) initiated a program to obtain engineering data on packaged, self-contained fire-suppression systems suitable for protecting advanced base facilities in arid, tropical, or extremely cold climates. Buildings at these advanced bases may be relatively small and are of lightweight, prefabricated construction. Their strategic importance is high, because shelter for personnel and equipment is essential for survival in polar or desert regions. Reliable fire protection is, therefore, vital for remote facilities.

The Factory Mutual Research Corporation under contract with the Naval Civil Engineering Laboratory (NCEL) evaluated 31 fire suppression agents and provided preliminary engineering data on five packaged fire suppression systems. The contractor recommended two systems for further development: the Halon 1301 Multicycle Total Flooding System and an automated water sprinkler system. The Halon system ranked first because of its many outstanding advantages. However, the time required to develop this system would be longer than for the water system. Therefore, in order to meet NFEC requirements for well-proven fire protection in the Antarctic in 1967, the Naval Civil Engineering Laboratory (NCEL) designed an automated, single-shot water system.

SCOPE OF THE INVESTIGATION

Design criteria for packaged fire protection systems were specified by NFEC and by a preliminary investigation conducted by NCEL. A consolidation of these criteria is as follows:

1. The system shall be adaptable to locations where normal water supplies are not available.
2. The system shall accommodate buildings with floor areas from 20 by 48 feet to 40 by 100 feet, with ceiling heights of 8 to 20 feet.
3. The system shall be either an incremental type or shall be composed of a family of sizes.
4. The system shall protect buildings constructed of the following:
   a. Steel panels for walls and roof (Butler type)

   b. Wood panel walls and composition roof
   c. Metal-clad panels for walls and roof

5. The system shall be adaptable for a wide variety of climates and environmental conditions, with temperatures ranging from -65° to +140°F.

6. The system shall be simple and compact so that it can be conveniently shipped by air as a packaged unit.

7. Assembly, installation, and maintenance shall not exceed the skill level of advanced base personnel.

8. The system shall be effective against Class A, B, and C fires.

9. Damage from extinguishants shall be minimum.

10. The system shall be selective.

11. The system shall be self-operative, or impose a minimum demand on power requirements.

12. The initial and maintenance costs shall be comparable to conventional systems.

It was unlikely that any one system would meet all of these criteria. It was therefore decided that the first four criteria and the suitability to -65°F weather would be mandatory and that trade offs between the others could be made to obtain the optimum system.

TECHNICAL APPROACH

In November 1964, Contract NBy-32287 was awarded to Factory Mutual Research Corporation (FMRC), Norwood, Massachusetts, for the purpose of obtaining engineering data on packaged automatic fire protection systems. Basic requirements of the contract were:

1. Establishment of the problem, with emphasis on obtaining more definitive design criteria.

2. Development of five or more system concepts.

3. Evaluation and ranking of the concepts in order from the most promising to the least promising.

4. Preparation of designs of the system concepts.

5. Recommendation of the one or two most promising systems for further investigation.

6. Findings to be reported

Research for System Concepts

The work accomplished under Contract NBy-32287 was completed in May 1965 by FMRC Report 15974.[1] In the report are included descriptions of five system concepts. A discussion of the five systems of Reference 1 as ranked by FMRC in descending order of potential development follows.

System Number 1: Halon 1301 Multicycle Total Flooding System. Fire detection is by tube and strut thermal switches located at various places in the protected area. Activation of any switch will open a pressurized supply tank of Halon 1301 and the gas will discharge to totally flood the confined space. If the fire should rekindle, a second shot of Halon gas will be discharged from a second supply tank. However, in order to obtain the gas concentration necessary for effective fire extinguishment, the protected space must be completely closed.

System Number 2: Automated Water Sprinkler System. Fire detection is by tube and strut thermal switches and by standard automatic sprinkler heads. The switches have a 140°F rating and the sprinkler heads have a 165°F rating. When any of the thermal switches are activated, a stored, pressurized tank of water will be set in readiness for operation. After the sprinkler heads are opened by heat, water will flow through the open heads for as long as the thermal switches sense the heat; the water will shut off automatically when the ambient air temperature decreases. If the fire rekindles, the thermal switches will again activate the water supply system, causing water to flow through the open heads. For arctic application, lithium chloride can be added to the water to prevent freezing.

System Number 3: High-Expansion Foam and Halon 1301. Fire detection is by tube and strut thermal switches. The three components of the foam — Halon 1301, water and foaming agent, and nitrogen — are stored in separate containers. Upon activation of any switch, the three tanks will open simultaneously, and the agents will flow in separate lines to foam generator heads mounted in the ceiling. At the generators, the components will mix to form high-expansion foam, the fire suppressant agent. Multicycling can be obtained with another set of tanks containing the three components.

System Number 4: Halon 1301 Single-Shot Total Flooding System. This system is similar to the first cycle of the Halon 1301 Multicycle System Number 1, except that ionization detectors are used to activate the system; these detectors respond faster to fires than the tube and strut detectors, but they will not recycle the system in the event of a rekindled fire.

System Number 5: High-Pressure Water Fog. Fire detection is by tube and strut thermal switches. When the system is activated, water under pressure of 100 to 1,000 psig will discharge through open fog nozzles. The thermal switch recycles the system, as does the detection circuit of the automated water sprinkler system.

Evaluation of System Concepts

NCEL used a numerical ranking chart to evaluate the system concepts developed and designed by FMRC. The chart is in Appendix A. The results of this evaluation, listed in order of the most promising to the least promising system, are as follows:

1. System Number 1: Halon 1301 Multicycle Total Flooding System
2. System Number 4: Halon 1301 Single-Shot Total Flooding System
3. System Number 2: Automated Water Sprinkler System
4. System Number 3: High-Expansion Foam and Halon 1301
5. System Number 5: High-Pressure Water Fog

An overall discussion of each system follows.

Systems Number 1 and 4: Halon 1301, Multicycle and Single Shot. The Halon 1301 systems have many outstanding advantages for NFEC buildings. They are compact and light for ease of transport and installation; the storage space for the suppressant agent is small and the agent is partially self-pressurizing and will not freeze. The simplicity of the mechanical parts minimizes installation and maintenance time. The extinguishant itself, Halon 1301, provides significantly greater fire protection per pound of agent than other chemicals now in use. It has extinguishing ability at all temperatures to -65°F; has a high dielectric strength, resisting breakdown when subjected to electrical stress; leaves no troublesome residue in the postextinguishment stage; has an exceptionally low toxicity both in the natural state and after changes brought about by exposure to heat; and is the safest vaporizing liquid* fire extinguishing agent known at the present time. Normal breathing and vision are possible for at least 2 hours in a 5% concentration of undecomposed Halon 1301 — an atmosphere that will not support combustion. No modifications are required to prevent freezing of the extinguishant or the system components. Halon 1301 is effective on Class A, B, and C fires, and causes little or no damage to the stored products. Fire suppression by a gaseous extinguishant has the additional advantage that the extinguishant totally disperses in the protected area, penetrating cracks and small openings within stored boxes and crates to extinguish deep-seated fires. As with all gaseous fire extinguishing agents, the extinguishant supply must be designed to totally flood and persist in the protected space in a definite concentration for a certain time. The persistence is necessary because the gas provides little or no cooling and thus the atmosphere must not support combustion until the burned material cools naturally.

* Technically, it is a liquified gas but it is generally referred to as a vaporizing liquid.

The price of Halon 1301 is from $2.67 to $3.50 a pound depending on the size of the container in which it is purchased. It is shown in Appendix B that a 10,000-cubic-foot building (20 x 48 x 10-1/2 foot), would require 170 pounds of Halon at a cost of $495. Halon 1301 is expensive, but its cost is offset by low weight, low initial cost of the system hardware, negligible operating cost, and by the high degree of effectiveness. Large-scale production of Halon 1301 is understood to be scheduled for 1967 and should reduce the price by about one-half.

System Number 2: Automated Water Sprinkler System. Outstanding advantages of the water system are that it is suitable for any building (closed or open), selective protection can be obtained, and the time needed for final development is the least of all systems considered because of work previously accomplished.[2] In addition, water would be more readily available than other fire suppressant agents at most advanced bases, and in general, base personnel are more familiar with the operation of water systems. Disadvantages are that system modifications are required to prevent freezing; its suitability is limited to Class A fires, water damage following activation is high, and suppression time is limited by the capacity of the storage tank. However, with suitable sprinkler heads, sprinkling times of 10 minutes can be obtained; this may be ample to keep fires suppressed until the firefighters arrive.

System Number 3: High-Expansion Foam and Halon 1301. The foam appears to be a desirable fire suppressant agent because it combines many of the advantages of both Halon 1301 and water into one agent. However, the foam system described in Reference 1 is too complex for advanced base use. Reference 1 also states that water solutions which do not freeze below -20°F are not good foaming agents; this makes the system unsuitable for cold climates.

System Number 5: High-Pressure Water Fog. The water fog system has most of the characteristics of the water system and it has some advantages of its own, in that water storage requirements and water damage are reduced. These advantages, however, when compared to the water system, do not offset the disadvantages due to complexity of the system required for fog generation.

Fire Tests

Objectives and Approach. As a part of Contract NBy-32287, the contractor was to recommend the two most promising systems for fire tests. The systems recommended were the Halon 1301 Multicycle and an automated water sprinkler. After these systems were evaluated by NCEL, the decision was made to test them against fire. The Halon test results could apply to either a multicycle or a single-shot system because the extinguishing actions of both are essentially identical.

Contract NBy-62167 was subsequently awarded to FMRC which was to conduct 30 fire tests and to recommend a final system for further development. The contract was completed in November 1965 by FMRC Report 15974.1.[2]

Test Findings. Significant results of the fire tests are:

1. A Halon 1301 concentration of 3% by volume, or 1 pound for 85 cubic feet of protected space, was sufficient for control of the Class A test fires.

2. Complete extinguishment was usually obtained with Halon 1301 because it persisted and continued to be an effective suppressant agent.

3. Complete extinguishment was, in most tests, not obtained with water because suppression action occurred only as long as the surfaces were wet; the fires would sometimes become more deep seated after the water spray stopped.

4. When a deluge of water from four open heads was applied by rapid triggering of a thermal switch, the water was more effective and less was required than when application was by fusible-link heads.

DISCUSSION

The investigation and tests conducted by FMRC and studies by NCEL indicate that Halon 1301 is the most promising suppressant agent for polar regions. A somewhat similar finding was reached in 1952 when Bjorksten Research Laboratories, Inc., under contract to NCEL to develop arctic fire extinguishers, recommended that Halon agents 1202 and 2402 be adopted as standard for arctic use.[3] Bjorksten also indicated that the most significant advances in fire protection are likely to come from research on halogenated extinguishing agents.

Halon 1301 has been used successfully for several years for local applications such as hand extinguishers, and engine compartments of airplanes, helicopters and army tanks. Its potential for total flooding systems, however, has only recently been realized. Since 1965, many organizations have conducted research on such systems; several systems are now in use and others are under investigation. A listing of the known organizations, the applications, and the state of development is in Table 1. Also, the National Fire Protection Association has formed a committee on halogenated extinguishing agents to formulate a design code for fixed total flooding Halon 1301 systems. Indications, therefore, are strong that further development will lead to practical and economical designs for an advanced fire protection system.

Halon 1301 is but one of many halon agents (FMRC included 13 halons in their rating chart of suppressant agents and it is the only gaseous suppressant agent specified in the FMRC system concepts. NCEL therefore further investigated the characteristics of Halon 1301 and compared them with carbon dioxide (CO_2). This comparison was made because CO_2 is the most widely used agent for total flooding systems, and FMRC ranked it as the second most promising gaseous agent for NFEC requirements. Results (Appendix B) indicate that a Halon 1301 single-shot system costs $725 less than a comparable CO_2 system for a 20 x 48 x 10-1/2-foot building.

Table 1. Organizations Known to be Using or Investigating Halon 1301 Total Flooding Systems 1/

Name of Organization	Application	State of Development
Northwest Hydrofoils, Inc. Seattle, Washington	Passenger compartments of 3 hydrofoil ferry boats	In use
Atomic Energy Commission Mercury, Nevada	Instrument vans	Under investigation
U. S. Navy - NAVSSC Washington, D. C.	Passenger compartment of LVT personnel carrier	Under development
U. S. Army Warren, Michigan	Engine compartment of M-60 tank Engine compartment of M-113 tank	In use
Argonne National Laboratory Argonne, Illinois	Hot cells (radioactive test chambers)	Being installed
E. I. Du Pont Company Wilmington, Delaware	2 laboratories, 20,000 ft^3 each 1 laboratory, 6,000 ft^3 1 petroleum demonstration trailer	In use
National Aeronautics and Space Administration	Gemini and MOL passenger compartments	Under investigation
Boeing Aircraft Company Seattle, Washington	Passenger compartment of commercial jet airliners	Under investigation
Factory Mutual Research Corp. Norwood, Massachusetts	Conducting fire tests on paper, charcoal, wood, plastics, and flammable liquids; conducting analysis of atmospheres during extinguishment of fires in practical situations.	—

1/ Information received from Mr. Charles L. Ford of E. I. du Pont de Nemours Company, Wilmington, Delaware on 6/30/66.

The desirable characteristics of water as a suppressant agent are well known, and systems using water have been highly developed. A water system for use under almost any condition can be designed with off-the-shelf items. The problems, however, of water damage, large storage volume, and unsuitability for Class B and C fires still exist; the problem of prevention of freezing can be solved only by increased system complexity and expense.

A listing of approximate costs of the water system is in Appendix C. It may be noted that the cost of the 500-gallon, single-shot water system is $1,410; this compares closely with the CO_2 system at $1,457 but is almost twice as expensive as the Halon 1301 system at $732. It may also be noted from Appendix C that considerable costs may be incurred in preventing the water from freezing.

The investigations to date show that neither Halon 1301 nor water may be considered as a truly all-purpose, all-climate suppressant agent. Of 31 agents considered, however, these two were ranked as the most suitable.[1]

CONCLUSIONS

1. There is no extinguishing agent currently available that is ideally suited to all types of fires, climates, and buildings.

2. Results of tests conducted by the Factory Mutual Research Corporation and studies by NCEL indicate a packaged system using Halon 1301 would provide the best fire protection at the least cost for small, sealed buildings in all climates.

3. In a closed building, complete fire extinguishment with a Halon 1301 system is reasonably well assured because the suppression action will persist until the building is ventilated; follow-up action by a fire-fighting crew, therefore, will not be required.

4. A packaged system using water is the most suitable one for large buildings which are not closed and where selective protection is required.

5. Complete fire extinguishment cannot be assured with a packaged water system because suppression time is limited by the capacity of the storage tank.

6. The cost of fuel to prevent freezing of water systems can be quite high in some remote areas.

RECOMMENDATIONS

1. The research being conducted by others on halon systems should be followed so that new developments may be applied to Navy fire protection systems.

2. The Halon 1301 system should be further developed for specific Navy uses and tested in both normal and cold climates.

3. The NCEL water sprinkler system should be field tested in the Antarctic so that conclusive data for final design specifications may be obtained.

4. Because Halon 1301 and water were ranked in the studies as the two best all-around fire suppressant agents, the Naval Facilities Engineering Command should have design specifications prepared for two systems, one using Halon 1301 and the other using water.

ACKNOWLEDGMENT

The services of Mr. S. L. Phelps and members of the Design Division who assisted in the design of the water sprinkler system are gratefully acknowledged.

Appendix A

NCEL SYSTEM RANKING CHART

System Characteristics	Name of System				
	Halon 1301 Multicycle	Automated Water Sprinkler	High-Expansion Foam	Halon 1301 Single-Shot	High-Pressure Water Fog
Suitable for building sizes specified	1	3	3	1	3
Simple and compact	3	2	0	3	1
Suitable for temperatures specified	3	1	0	3	1
Selective protection	0	3	2	0	2
Suitable for Class A, B, C fires	3	0	2	3	0
Low damage from suppressant agents	3	0	2	3	1
Low power requirements	3	2	0	1	1
Total Score	16	11	9	14	8

Scoring Code: 3 - Excellent
2 - Good
1 - Fair
0 - Poor

Appendix B

A STUDY OF HALON 1301

TECHNICAL DESCRIPTION

Halon 1301 (bromotrifluoromethane, $CBrF_3$) belongs to a family of halogenated hydrocarbon fire suppression agents. It is gaseous at normal room temperature and pressure, but it may be liquified by compression for storage; it is thus classified as a liquified gas.[4] The gas is colorless, relatively nontoxic, noncorrosive, and it will not conduct electricity.[5] A curve indicating the vapor pressure - temperature relationship is shown in Figure B-1. It may be noted that the vapor pressure is 200 psia at 70°F and 18 psia at -65°F. Thus at normal room temperature, the Halon 1301 is adequately self-pressurizing but at lower temperatures additional pressurization is required. Nitrogen may be used as a pressurizing agent. Other significant characteristics are:

Molecular Weight	148.9
Boiling Point	-72.0°F
Freezing Point	-270.4°F
Density of Liquid	98.0 lbs/ft^3

A complete list of its physical properties is given in Reference 5.

The various halon agents are usually identified by the numerals given with the word "halon," and the numerals represent the following number of atoms: 1st digit, carbon; 2nd digit, fluorine; 3rd digit, chlorine; 4th digit, bromine; 5th digit, when used, iodine.[4] Halon 1301 is thus composed of 1 carbon atom, 3 fluorine atoms, and 1 bromine atom. In a halogenated hydrocarbon, the fluorine lowers the boiling point, increases stability, and reduces toxicity.[6] The bromine increases the density and improves the fire-fighting characteristics.[6] Halon 1301 is the most effective of the halogen hydrocarbon atoms for firefighting.[7] It is interesting to note that the addition of a second bromine atom is not beneficial.

The relative effectiveness of Halon 1301 is quite high, as compared with other chemical agents; on a weight basis, if a value of 100% were assigned to Halon 1301, dry chemical sodium hydrogen carbonate would be about 66%, carbon tetrachloride about 34%, and carbon dioxide about 33%.[8] Because of this high efficiency and high liquid density (1.57 times heavier than water), only a small storage volume of Halon 1301 is required for packaged fire protection systems.

Although the present cost of Halon 1301 is high, it is understood that large scale commercial production is scheduled for 1967 and the prices shown in Table B-1 may be reduced by about one-half.

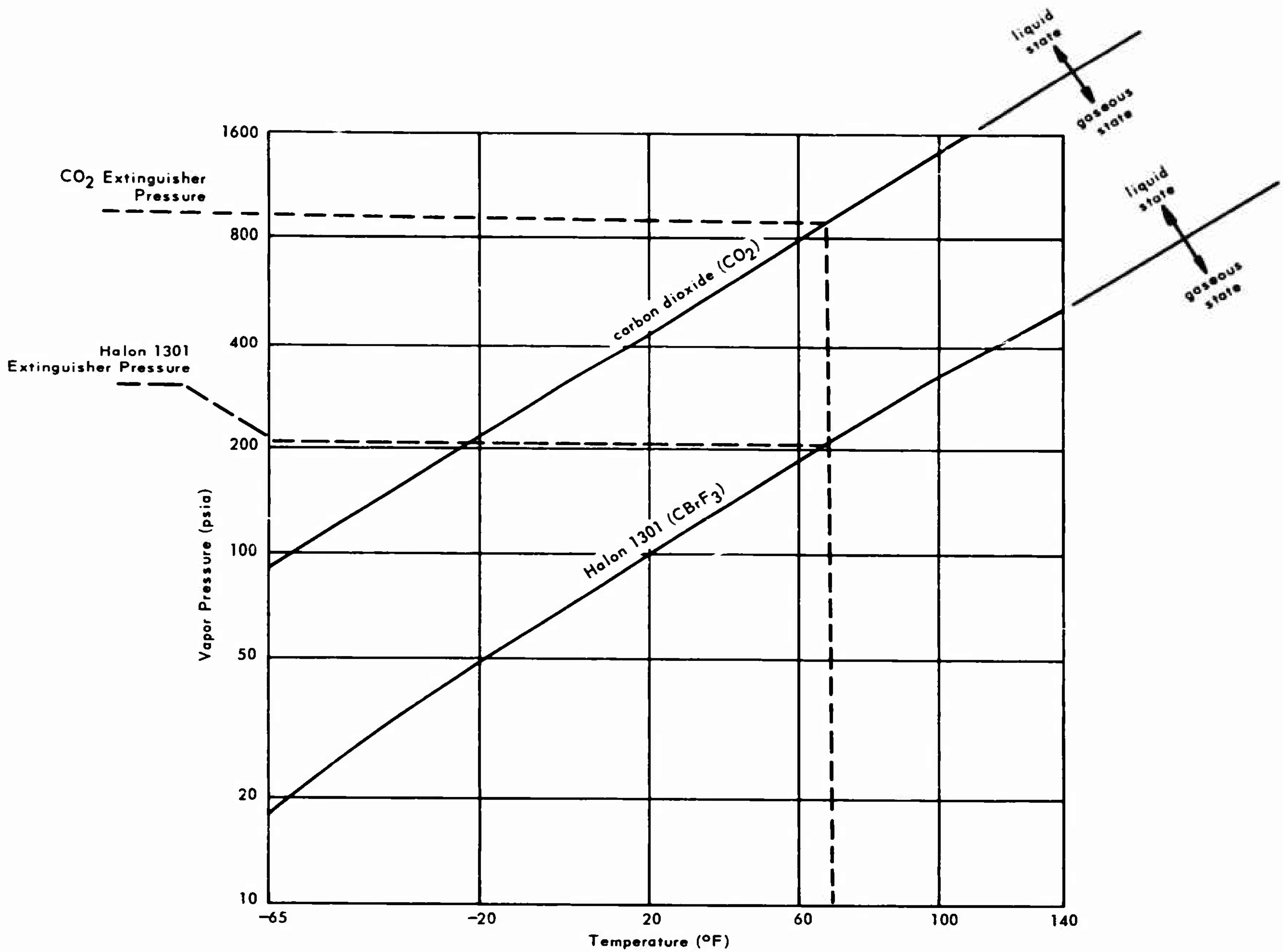

Figure B-1. Vapor pressure versus temperature for Halon 1301 and carbon dioxide.

Table B-1. Comparison of Halon 1301 and CO_2

Characteristic	Halon 1301	CO_2
Relative volume concentration of agent needed to extinguish a fire	1	10
Relative weight of agent needed	1	3
Relative liquid volume of agent needed	1	6
Relative strength of containers and piping	1	4.5
Pounds of agent required for:		
140 cu ft	3	10
500 cu ft	11	34
1,600 cu ft	32	101
4,500 cu ft	77	252
50,000 cu ft	800	2,500
Cost of agent per pound (dollars):		0.05 1/
2,000-lb tank	2.67	
150-lb cylinder	2.91	
28-lb cylinder	3.16	
10-lb cylinder	3.41	
6-lb cylinder	3.50	

1/ Approximate cost per pound for all quantities.

TOXICITY

Halon 1301 is generally regarded as nontoxic; however, when toxicity is defined as a measure of the amount of a chemical which can be inhaled in air without adversely affecting a human being, Halon 1301 is not completely nontoxic. The Underwriters Laboratories classify it in the undecomposed state, as a Group 6 gas.[9] Reference 9 defines a Group 6 gas as one in which concentrations up to 20% by volume, for 2 hours, do not produce injury. The 5% by volume concentration, which has been specified for packaged systems is, therefore, far below the toxic level and personnel without gas mask protection could safely enter a room that has been flooded with a 5% concentration of gas.

Halon 1301 becomes considerably more toxic when it is broken down by heat from a fire; however, it is safe in its decomposed state in concentrations up to 2% by volume.[9] The amount of Halon 1301 that would be decomposed depends upon the size and temperature of the fire and, thus, the prevailing concentration cannot be predicted. In terms of toxicity, decomposition of Halon 1301 is of small consequence, since the fire is extinguished very rapidly. Halon 1301 vapor that comes in contact with flame breaks apart into chemical radicals that immediately stop the flame from burning. Also, in a fire environment, the toxicity contribution of the decomposed Halon 1301 is probably small when compared to the toxicity of carbon monoxide generated by the fire itself. It is known that carbon monoxide is lethal in concentrations of more than 1.5%. Tests by the U. S. Army Chemical Corps have indicated that within about a minute, lethal concentrations of carbon monoxide and carbon dioxide occur from a fire in a closed but normally ventilated space.[9] This makes it necessary for persons entering a room after the fire has been extinguished to use suitable breathing apparatus regardless of the toxicity of decomposed fire suppressant agent.

COMPARISON OF HALON 1301 WITH CO_2

The type of total flooding system that has been the most common over the years employs carbon dioxide (CO_2). FMRC ranked CO_2 as the second most promising gaseous suppressant agent and as the sixth most promising of all 31 suppressant agents considered. Disadvantages of CO_2 are: the high concentration needed for extinguishment (about 40%) would cause asphyxiation within about 5 minutes; the liquid volume required is 6 times larger and 3 times heavier than that of Halon 1301; the high vapor pressure requires high-strength cylinders, piping, and valves. A curve showing vapor pressure versus temperature of CO_2 is in Figure B-1; the dotted line illustrates the pressure difference between CO_2 and Halon 1301 at 70°F. A tabulation of significant differences in characteristics is in Table B-1. It may be noted that the amount of agent needed per cubic foot of protected space decreases with increasing building size; this is because building volume increases at a greater rate than does wall area, where leaks occur.

Figure B-2 is a sketch of a typical total flooding system. A list of the principal items of the systems and costs for a 10,000-cubic-foot building are in Table B-2. Detection equipment is not included.

There are, of course, other items required for a complete system, but the costs should be essentially the same for both systems. It is therefore apparent that the Halon 1301 system is cheaper to purchase than the CO_2 system, and the reduction in required hardware would make it cheaper to ship to remote bases.

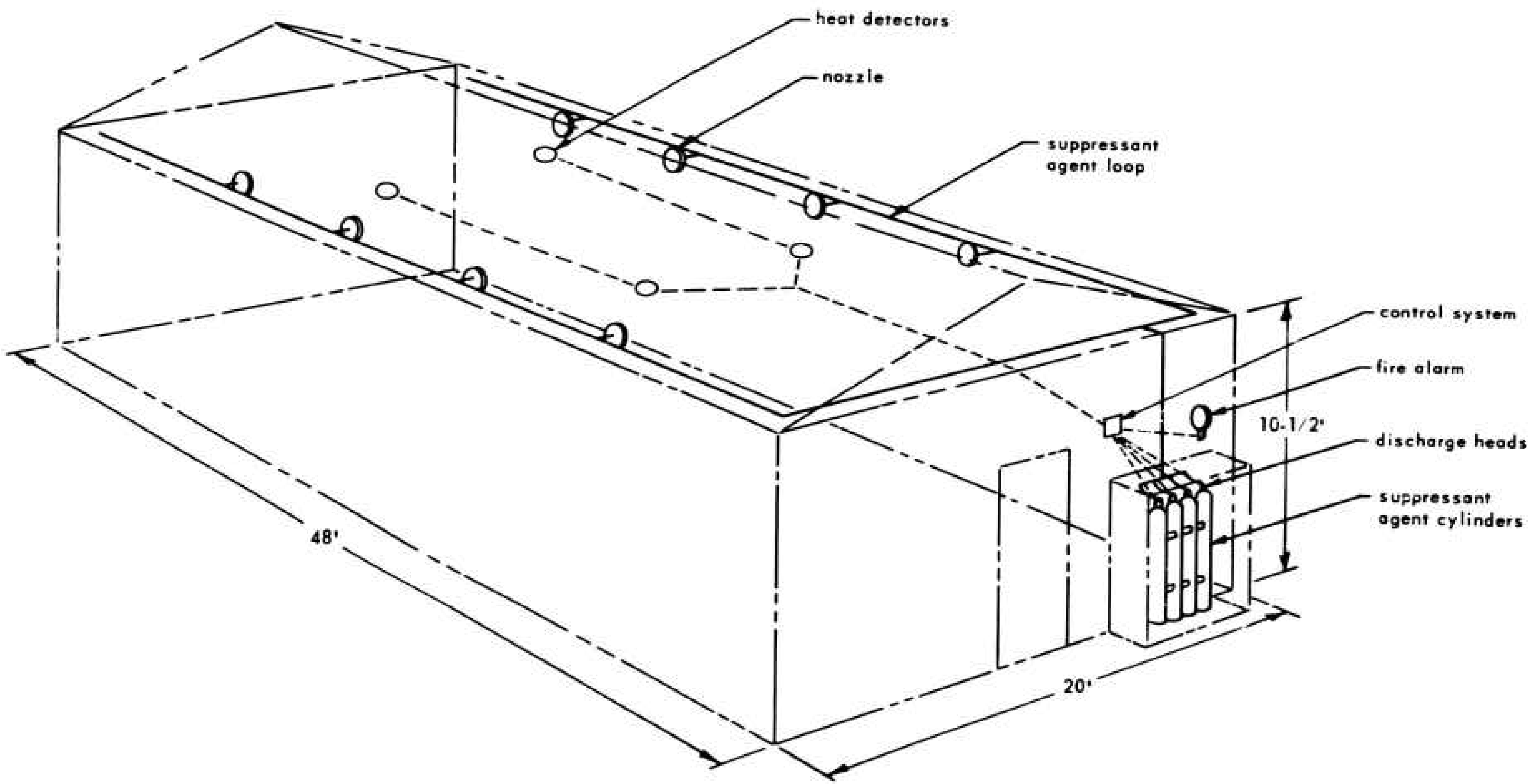

Figure B-2. Typical self-contained, fixed, total flooding system.

Table B-2. Cost Comparison of Halon 1301 and CO_2 Systems for a 10,000-Cubic-Foot Building 1/

Item	Halon 1301 System		CO_2 System	
Suppressant agent	170 lb at $2.91/lb:	$495	510 lb at $0.05/lb:	$ 25
Containers	two 100- to 150-lb cylinders at $30 each:	60	eight 75-lb cylinders at $115 each:	920
Discharge heads	$30 per cylinder:	60	$30 per cylinder:	240
Cylinder supports	$8 per cylinder:	16	$8 per cylinder:	64
Manifold	$10 per cylinder:	20	$10 per cylinder:	80
Piping for distribution		40		115
Discharge nozzles 2/	three at $7 each:	21	nine at $7 each:	63
Auxiliary pressurization for arctic use	Nitrogen with cylinder and regulator:	100	not required	
Total		$812		$1,507

1/ Detection and control items are not included.

2/ The CO_2 system requires more nozzles than the Halon 1301 system because of the larger volume of agent to be discharged.

Appendix C

NCEL PACKAGED AUTOMATIC SPRINKLER SYSTEM

REQUIREMENTS

The Naval Facilities Engineering Command had urgent requirements for a developed and tested fire protection system for Operation Deep Freeze in 1967. In order to meet this requirement, a water sprinkler system was chosen for further development. Work had been performed by NCEL on a sprinkler system;[10] therefore, less time was required to obtain final design specifications for a sprinkler system than for a gaseous system. The system is for a well-established facility which has modem and reliable electrical power and where water supplies, while not plentiful, are ample for packaged sprinkler systems.

DESCRIPTION OF THE SYSTEM

The NCEL fire protection unit is a single-shot, fully automated water sprinkler system. It is similar in operation to the one described in NCEL Report R-067,[10] except that the number of control elements was reduced for increased reliability. The overhead distribution piping system and sprinkler heads were not included with the rest of the system; they must be designed separately to meet individual requirements.

Water is stored in tanks that hold 500, 750, or 1,000 gallons of liquid plus a 10% allowance for air space.* Pressure is furnished by nitrogen, which flows from high pressure cylinders when the sprinkler heads are actuated by heat. Electric heaters are used to prevent the stored water from freezing. Two possible heating systems were studied: (a) immersion heaters in insulated tanks, and (b) electric heat to warm the ambient air in a sealed and insulated compartment which will contain the entire water storage system. Heat transfer calculations showed that both heating systems consume approximately the same amount of power. Plans and details of the system using an insulated tank with immersion heaters are in Reference 11. The approximate price of the 1,000-gallon system with an insulated tank is $2,185; a price breakdown of each system is given in Table C-1.

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*The air space is to prevent the tank from bursting if it should freeze.

Table C-1. Approximate Prices of the NCEL Packaged Automatic Water Sprinkler System 1/

Item	1,000 Gallon System	750 Gallon System	500 Gallon System
Storage tank	$1,000	$ 750	$ 500
Tank insulation	200	175	150
Nitrogen cylinders	240 2/	200 3/	160 4/
Nitrogen gas	120 2/	100 3/	80 4
Pressure regulator	75	75	70
Manifold	60	50	40
Frame for cylinders and tank	150	140	130
Heaters	45 5/	45 5/	45 5/
Thermostats	60 5/	60 5/	60 5/
Magnetic contactor	35	35	35
Fused disconnect switch	25	25	25
Sprinkler heads	25	20	15
Valves and piping	150	125	100
TOTAL	$2,185	$1,800	$1,410

1/ Costs of electrical triggering items and fuel are not included.
2/ Cost of six cylinders and gas for charging them, respectively.
3/ Cost of five cylinders and gas for charging them, respectively.
4/ Cost of four cylinders and gas for charging them, respectively.
5/ Cost of three units.

Water and Nitrogen Subsystem

A flow diagram of the water and nitrogen subsystem, reproduced from Reference 11, is shown as Figure C-1.

The water tank is filled through valve 4. Valve 9 must be open during filling to vent the tank and to indicate when it is full. The tank may be drained by valve 10. At standby, the pipe header and all attached sprinkler lines are filled with nitrogen to 60 psig pressure, instead of water, to prevent freezing. Gas pressure is maintained in the lines and in the water tank (11) by a pressure regulator (2) which is connected to nitrogen cylinders (5). A rupture disk (6) prevents water from entering the pipe header until the system is activated. In the event of high tank pressure due to malfunction of the regulator (2), a safety valve (8) will open and relieve the excess pressure. A rupture disk (7) between the tank and the safety valve is specified because safety valves under pressure often leak.

When any of the fusible link heads in the sprinkler lines open due to heat, pressure in the line downstream of rupture disk 6 will drop; at 40 psig differential pressure, the rupture disk will break, and the system will be activated. A flow restrictor (3) will divert the flow of nitrogen into the water tank (11), and water will flow from the tank into the sprinkler header. Flow will continue until the water tank is empty, or until valve 1 is manually shut off.

The system is made ready for service by opening throttle valve 1, allowing nitrogen to fill the lines to 60 psig pressure. Gas flow must initially be regulated by the throttling valve so that pressures on each side of rupture disk 6 are about equal. Pressures may be observed on the gages (14), and the flow rate can then be adjusted as necessary. After the line pressure reaches 60 psig, the throttling valve must be left fully open. All lines should be checked for leaks at 80 psig line pressure before the system is charged with nitrogen; the rupture disk and safety valve should be removed before the leak test is conducted.

Absorption of the nitrogen gas by the water is insignificant. Calculations from data of Reference 12 show that water in the 1,000-gallon tank will absorb approximately 2-1/2 standard cubic feet of nitrogen. This is about 1.1% of the capacity of one nitrogen cylinder.

Heating and Alarm Subsystem

A wiring diagram of the heating and alarm subsystem is reproduced from Reference 11, and is shown in Figure C-2. The heating method utilizes three 1-kw electric immersion heaters (22) that are connected to 120/208-volt, 3-phase, 4-wire, 60-cycle electric power supply by a fused disconnect switch (23). A thermostat (19) will control the heater through contactors (20) and maintain the water temperature at approximately 45°F. In the event of failure of the heating system, the 39°F thermostat (17) will turn on the low-temperature warning light (16). The 65°F thermostat (18) will turn on the high-temperature warning light (23) if the heaters fail to go off. The water temperature may be observed on a thermometer (12). The water indicator (15) will turn on the water level warning light (24) when the water drops below a specified level. The three warning lights should be labeled and mounted on a control panel.

Steady-state power requirements and heater operating cycles are shown in Table C-1 for -65°F (the lowest design temperature) and for -20°F. Heat transfer calculations for the 1,000-gallon tank indicate, that to maintain a water temperature of 45°F in an ambient temperature of -65°F, the heat loss from the tank will be 2,800 Btu/hr. A 1-kw heater, operating approximately 90% of the time, would be adequate to prevent the water from freezing; three 1-kw heaters are specified to provide reserve capacity in the event of an emergency. After normal operating temperature is reached, two of the heaters may be disconnected from the line by a switch (21) to prevent the power supply from being unnecessarily loaded.

Figures C-3 and C-4 were prepared to give field personnel an indication of how much time is available for repairs before the water freezes. Figure C-3 shows the number of days for the water temperature to drop from 45°F to 32°F; Figure C-4 shows the number of days for the water to freeze solid from 45°F.

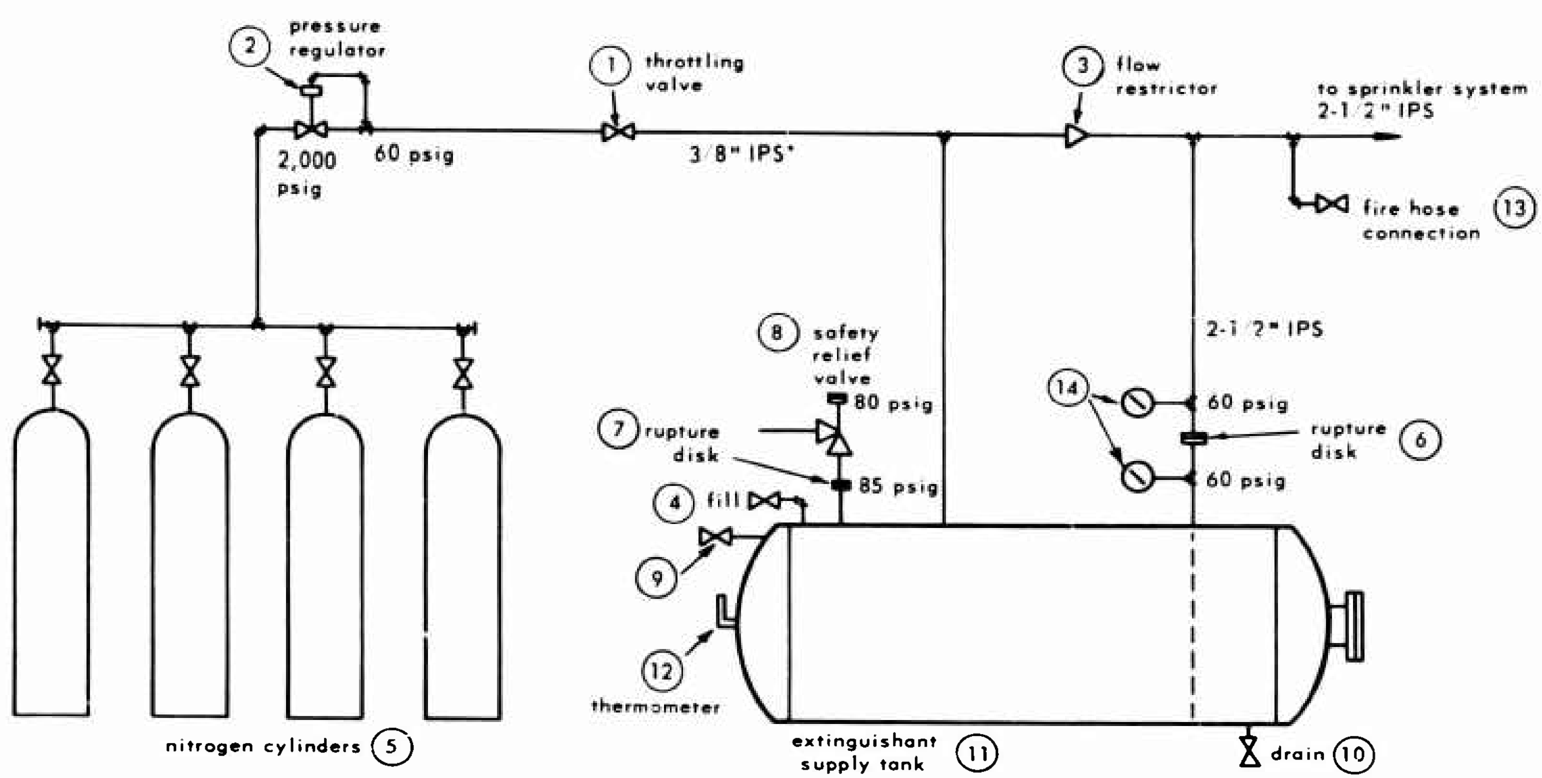
An alternative method of preventing the water from freezing is to install the packaged water system in a sealed and heated enclosure; the enclosure will be 8 x 8 x 12 feet and insulated with 3-inch-thick rigid slab urethane foam. The enclosure may be heated by either one of two methods: (1) As shown in Figure C-2, the tank insulation is omitted, permitting heat dissipation from the tank to the enclosed atmosphere. (2) The air in the enclosure is heated with electric strip heaters — three 1-kw strip heaters instead of immersion heaters, and an air thermostat instead of the 45°F water thermostat.

Fuel requirements to prevent the water in the 1,000-gallon tank from freezing were estimated by assuming that the average annual temperature is -20°F and that electric power is supplied by diesel generators that are 30% efficient. (See Table C-2 for power requirement.) Calculated from the average Btu yield, the diesel fuel needed would be 0.89 gallons per day. In Reference 13, fuel costs at antarctic bases are estimated to be from $0.50 to $3.87 per gallon, depending on the delivery point and the assumptions used in the calculation. Using the lower estimate, it will cost $0.45 a day, or about $164 a year to heat the water. It should be noted, however, that for certain locations the fuel costs could be higher by a factor of 7.75, and for -65°F temperatures, the heating requirements could increase by a factor of about 2 (see Table C-2). It is conceivable, therefore, that in extremely cold and remote locations, the fuel cost could be as high as $2,542 a year ($164 x 2 x 7.75).

Table C-2. Operating Characteristics at Two Air Temperatures of Water Storage Tanks Insulated With 2-Inch-Thick Polyurethane Spray Foam

Operating Characteristic	Water Tank Size (gal)					
	500		750		1,000	
	-20°F	-65°F	-20°F	-65°F	-20°F	-65°F
Power required to maintain water temperature at 45°F (kw-hr)	0.33	0.62	0.37	0.67	0.45	0.82
Heater operating time required to raise water temperature from 40°F to 50°F (hr)1/	3.7	5.2	5.0	7.9	9.6	11.2
Time for water temperature to drop from 50°F to 40°F (hr)	37.2	20.0	20.0	27.3	54.5	30.5

1/ Using three 1-kw immersion heaters.



*IPS – iron pipe size

Figure C-1. Flow diagram of water and nitrogen subsystem.

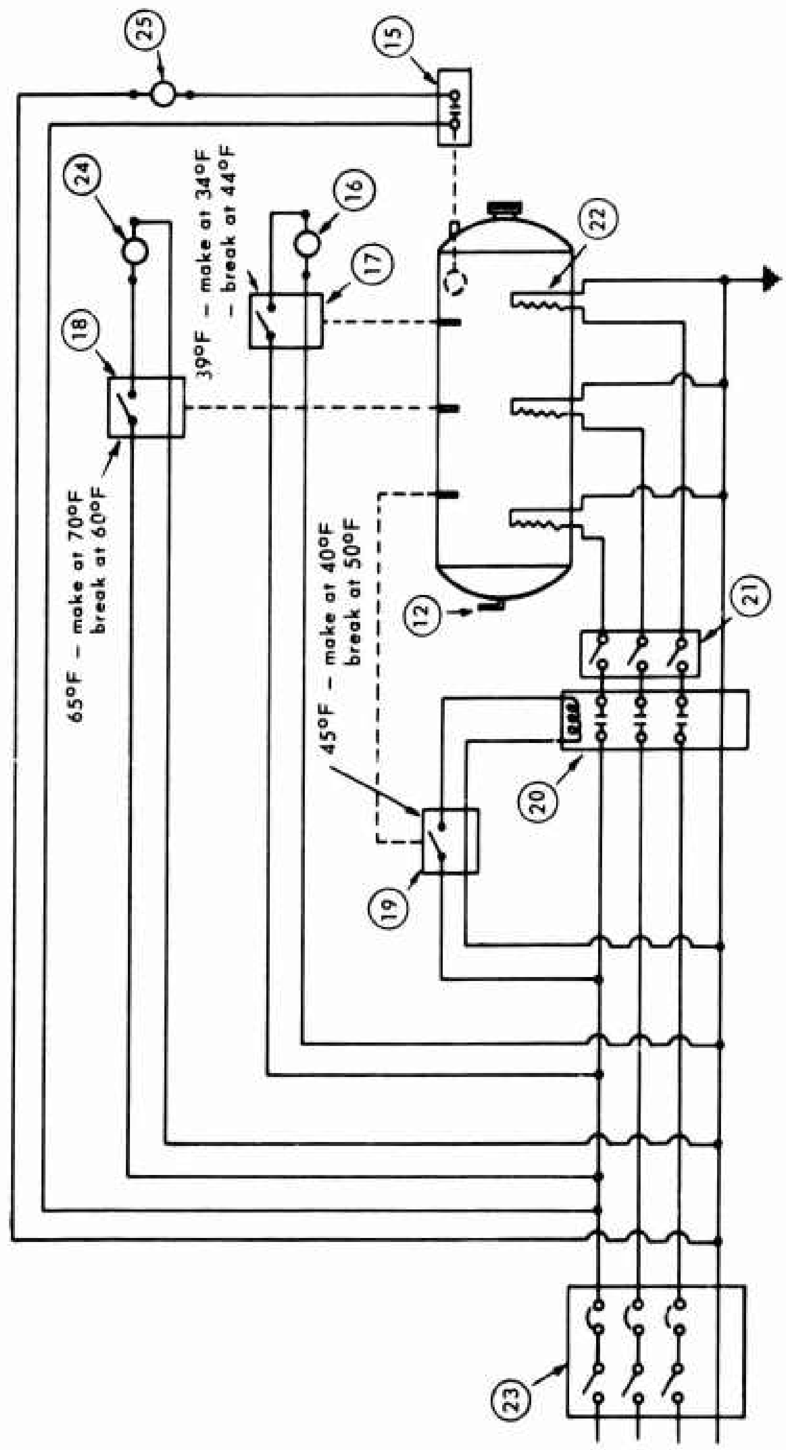


Figure C-2. Wiring diagram of heating and alarm subsystem.

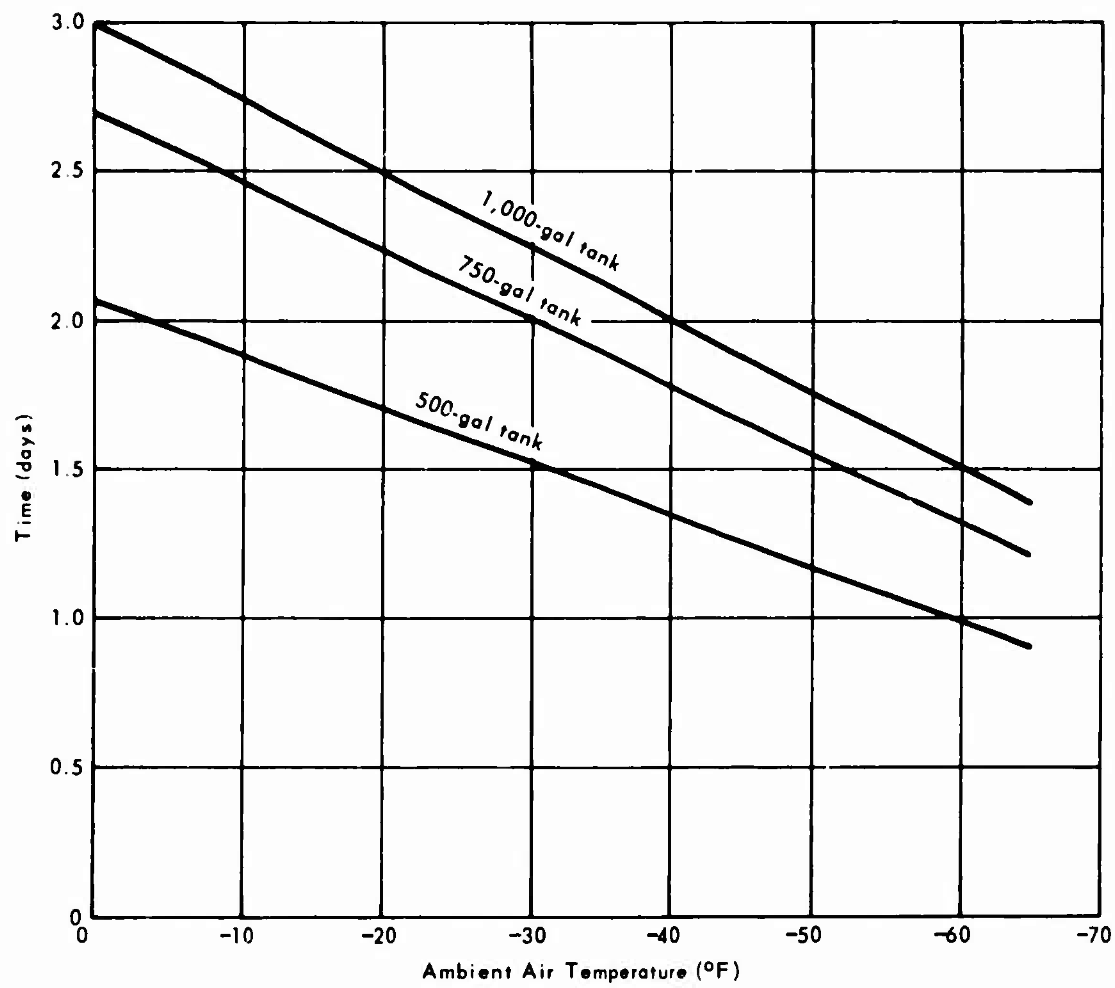


Figure C-3. Time required for stored water to cool from 45°F to 32°F at various ambient air temperatures.

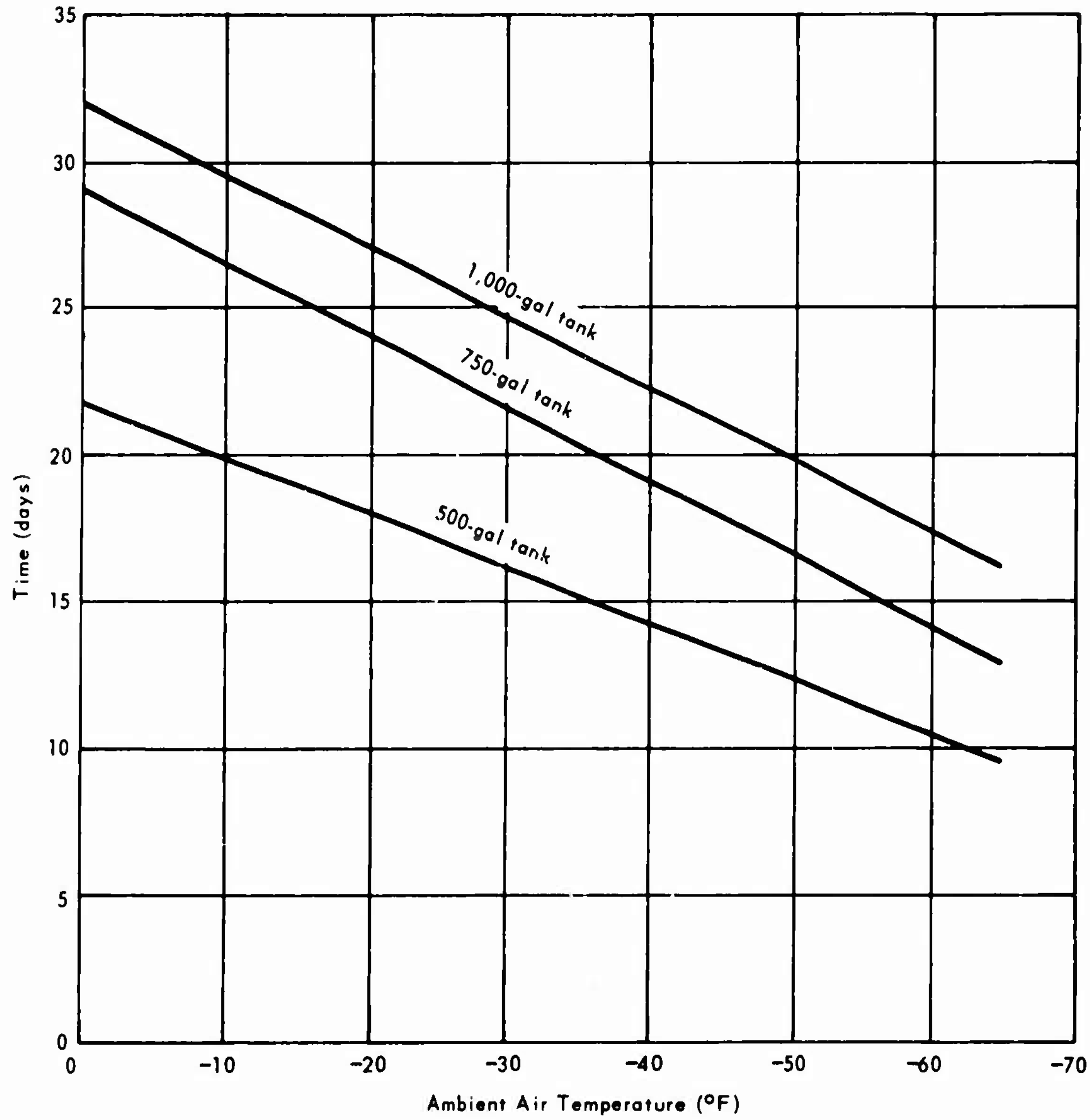


Figure C-4. Time required for stored water (45°F) to freeze solid at various ambient air temperatures.

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13. ABSTRACT

The Naval Facilities Engineering Command has requirements for packaged automatic fire protection systems suitable for use in any climate, including polar. A research firm under contract to NCEL evaluated 31 fire-suppressant agents, and prepared conceptual designs of five protection systems, ranking the concepts on the basis of fire extinguishing characteristics, initial and maintenance costs, and reliability. The Halon 1301 Multicycle Total Flooding System was first choice and an automated water sprinkler system was second choice. Fire tests of these two systems by the contractor indicated that the Halon 1301 system is the more promising for an advanced base in a polar climate. However, because a fire protection system was required for immediate use in the Antarctic and the Halon 1301 system would require considerable development time a water sprinkler system already proven in service was selected. This system designed by NCEL and discussed in this report is fully automated. It is a single-shot system, pressurized with nitrogen, and uses electric heaters to prevent the stored water from freezing.

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